WH

Selenography,

OR

WHAT ASTRONOMERS SAY OF THE MOON

A PAPER READ BEFORE THE

Hamilton Association

BY

H. B. WITTON, ESQ.

Jan. 13th, 1881.

HAMILTON:
SPECTATOR PRINTING COMPANY.
1881.

Can.
Pam
W

Witton, Henry B.

SE

Except the
bodies has at
moon. Her s
subdued sple
erratic cours
ing of her pha
currence and
have al. cont
memorial an
this the oldes
attest. The
the oldest s
show that in
phases of the
fluence was i
languages he
days of the
tiquity of th
Laplace long
of the week a
astronomical
modern, has
nyth and fan
has been fain
watch her wi
osophy has v
of cosmical h
to contribute
spheres. And
fathers, by s
—thought to
left by them
unmistakably
to the moon's
It is true th
merly paid to
though the a
pired with the
succeeded by
which retains
their errors.
our cattle, pr
vests and vi
but our lunar
servatories sh
fluence. Th
did not die ; i
consideration
a constituent
study of her
world we live
like a halo ar
and supersti
but happily it
almost impe
line of our
prosaic, know
The moon i
pears to follo

SELENOGRAPHY

Or What Astronomers Say of the Moon.

By H. B. WITTON, Esq.

Except the sun itself, none of the heavenly bodies has attracted so much attention as the moon. Her size and nearness to the earth, the subdued splendor of her light, her apparently erratic course in the heavens, the rapid changing of her phases, with the frequency of their recurrence and the weird effects of her eclipses, have all contributed to make her from time immemorial an object of interest. To the truth of this the oldest and most recent literatures alike attest. The Sutras and Vedic hymns of one of the oldest stems of the Indogermanic race show that in the early dawn of civilization the phases of the moon were personified, and her influence was invoked with solemn rites. In many languages her name has been given to one of the days of the week. This in itself proves the antiquity of the respect she has commanded, for Laplace long since showed the names of the days of the week are the most ancient monuments of astronomical knowledge. Poetry, ancient and modern, has thrown around her lovely veils of myth and fancy. The most prosaic utilitarianism has been fain, in the interests of commerce, to watch her with unremitting attention, and philosophy has vied to do her honor. In his system of cosmical harmony Pythagoras conceived her to contribute the highest tone to the music of the spheres. And our own less imaginative forefathers, by such names as lunar caustic, selenite—thought to be moon froth—and lunatic, words left by them as a legacy to our current vocabulary, unmistakably show the potency they attributed to the moon's influence.

It is true the kind of respect which was formerly paid to our satellite no longer exists. But, though the age of faith in her occult powers expired with the astronomer and alchymist, it was succeeded by an age of inquiry and knowledge which retains their devotion and has outgrown their errors. We no longer plant and sow, herd our cattle, prune our vines and gather our harvests and vintages in awe of her sovereignty; but our lunar tables, nautical almanacs and observatories show we have not yet ignored her influence. The old spirit of respect for her power did not die; it was transformed to a more exact consideration of her position and importance as a constituent part of the solar system, and to the study of her purely physical influence on the world we live in. The charmed circle, thrown like a halo around her by astrological ignorance and superstition, had a fascinating attraction, but happily it was evanescent and faded away almost imperceptibly into the clearer outline of our more positive and useful, if more prosaic, knowledge.

The moon in her path through the heavens appears to follow the sun, but lags a little further behind him every day. The amount she thus falls back is a variable quantity, and it has, as we shall see, given the astronomers no little trouble to foretell what it would be. But taking one day with another it averages about fifty minutes each day, or a space in the heavens covering an angle of 12 deg. 30 min. So in about seven days after new moon she is in her first quarter, about 6 hours or 90° behind the sun, and shows his reflected light from the western side of her disk. In about seven days more she is about twelve hours or 180° degrees behind the sun, and appears to us as full moon. In about another seven days she is eighteen hours or 270° behind the sun and shows us his reflected light from the eastern part of her disk; as she is then in her last quarter. In about seven days more she rises and sets with the sun, and is again new moon. In going through this series of phases the moon more than completes the circuit of her own orbit round the earth. For the earth itself during a lunation is carried forward in its movement of translation round the sun, about 30°, which distance the moon has to pass over before sun, moon and earth can take the relative positions to each other they must have at time of new moon. This lunation, or course of the moon once around the earth, and far enough on in a second revolution to appear to us to exactly rise and set with the sun, is called the moon's synodical revolution. Take one circuit with another, the time for making it is 29 days, 12 hours, 44 minutes and 3 seconds. The mean time it takes for the circuit of her own orbit only is but 27 days, 7 hours 43 minutes and 11 seconds. Thus, in each lunation the moon, because of the earth's motion in its path round the sun, proceeds 2 days, 5 hours and 52 seconds on another course round the earth before she comes into the necessary alignment with the sun and earth to again present to us the phenomenon of new moon.

Astronomical science regards the heavenly bodies in two aspects: in their relations to time and space, and as masses of matter moving in obedience to cosmical forces. As the latter conception could only spring from ages of investigation, ancient astronomy was mainly engaged in keeping a watch on the times and seasons. In this early stage of astronomical research, the moon received a full share of attention.

Philologists tell us the word moon can be traced to a primitive root which means the measurer; and it is certain lunations from time immemorial, have been used as a measure of time. But though a lunation possesses many requisites for a standard measure of time, it has been found by no means easy to divide by it the period which elapses during the earth's departure from and return to the vernal equinox—the

year of seasons, or what the astronomers call the tropical year. And whenever chronologists have adopted the lunisolar year for their record of time, they have been driven to adopt intercalations and devices to keep their months and years from overlapping. This is seen in the Greek Olympiads, which are tabulated from 770 B. C. to 220 A. D. They originated from holding at Olympia national games for four or five days in succession at the time of the first full moon after the summer solstice. The celebration of religious observances at the proper times and seasons made it obligatory with the Greeks to have a correct division of time into days and months and years; and taking, as they did, the time of the earth's motion around the sun to determine their year, and that of a lunation for their month, their calendar was not kept right without trouble. For a long time their months alternately comprised 29 and 30 days; but as a lunation is not the exact mean between the two, they were compelled to arrange occasional corrections. One of these correctional devices was the celebrated Cycle of Meton. It was adopted four hundred and thirty-two years before the Christian era, and shows how accurately the Greeks then knew the time it takes the earth—or as they thought the sun—and the moon, to make their circuits of translation. This cycle included a period of nineteen years, seven of which had thirteen, the remainder but twelve months each, making for the cycle 235 months. One hundred and ten of these months were called hollow, and had but 29 days each, and one hundred and twenty five were called full and had 30 days each. This arrangement gave the cycle of 19 years, 235 months, made up of 6,940 days. As this number of days is only 9½ hours more than 19 tropical revolutions of the earth, and 7½ hours more than 235 lunations, there was but a small discrepancy left for subsequent correction. This cycle, called the Golden Number, is still used to determine the time of Easter, as the Sunday following the first full moon after the vernal equinox was long ago appointed by ecclesiastical authority to be observed as Easter Sunday. So through these long centuries, there is a direct link between the time of our Christian observances and the old Greek astronomers who took the motions of the moon as a measure of time.

Astronomers contend that the lunar motions strictly accord with, and lucidly illustrate, the fundamental principles of their science. A comprehensive statement and elucidation of what these principles are would tax the skill of a specialist who had given to their study the devotion of a lifetime Still, a cursory glance suffices to show they are primarily based on the conception of Copernicus, that the earth has a daily axial rotation and an annual translation round the sun; on the discoveries of Kepler, that the form of a planet's orbit is an ellipse about its primary as a focus; that the areas swept by the radius vector of a planet are proportionate to the time of its motion; and that the squares of the periodic times of planets are in proportion to the cubes of their distances from the sun. If to these discoveries we add that of Newton, by which they are confirmed, namely the discovery that all bodies attract each other proportionately to their mass, and in inverse proportion to the squares of their distances, we have the foundation on which the astronomer has raised his magnificent structure. These laws of Kepler, are marvelous generalizations of the position and motions of the heavenly bodies, and become all the more so when we take into account that they were conceived under the influence of the astrological spirit of his times, and were mixed up with its most absurd fancies.

It is difficult to realize that the mind capable of so clearly explaining how the planets move, could satisfy itself the cause of their motion was that the sun has a soul, and in turning round he draws the planets to him; that they have a side friendly to him, and one that is hostile: When the friendly side is next him they are attracted, and when the hostile side is next him they are repelled. Yet even here error pointed to truth. The requirements of Kepler's theory led him to believe in the rotation of the sun, and twenty years after Galileo saw through his telescope the sun's rotation was a reality. The hypothesis of Newton has been substantiated by the most careful experiments and observations, and now ranks with our most exact knowledge. Results deduced from his theory have stood the most scrupulous comparison with the facts of actual observation. Some years ago eight thousand observations of the moon's position at different times during a period of eighty years were, under the direction of Professor Airy, compared with the place at which, according to Newton's theory, it would be at the time of each of these observations. Each theoretical place was computed separately and independently. The work took a body of calculators eight years, at a cost of £4,300, and the agreement fully sustained the truth of Newton's theory.

If the moon revolved around the earth subject only to the force of their mutual attraction, her orbital motion would present no peculiar difficulty to the expert astronomer. For we know the motion of the planet Jupiter was long ago so exactly calculated that predictions made some years in advance of the time he would pass meridians of different places, have corresponded to actual observation within half a second. But in addition to the attraction of the earth the moon is influenced by the attraction of the sun, and also to a slight degree by that of the planets near to her. Moreover from the moon's elliptic orbit, and the inclinations of the plane of that orbit to the plane of the ecliptic, the sun's attraction is a force constantly varying, both in degree and direction. Hence the calculation of the moon's orbital motion is one of the most difficult tasks ever accomplished in the whole field of physical astronomy. The data or orbital elements on which these calculations are based undergo, from the disturbing power of the sun, periodical variations corresponding to the inequalities of the moon's orbital motion. These lunar elements are given in almost all the better class of astronomical treatises. The "lunar inequalities" have been explained by the present Astronomer Royal, Prof. Airy, in his exposition of the force of gravitation. His book was written mainly for readers of limited mathematical education, and was declared by Lord Brougham—who had tried his hand at similar work—to be the best general explanation of the Newtonian philosophy ever written or ever likely to be written.

In addition to the purely astronomical value of so thoroughly ascertaining the motions of the moon as to be able to predict with exactness her place in the heavens at a future time, the desirability, in the interests of navigation, of achieving this was recognized in the latter part of the sixteenth century by all the advanced governments of Europe. The general extension of commerce which had resulted from the discovery of America, made it highly desirable to find some easy and exact method by which seamen could determine the longitude at sea. Almost every mode of ascertaining longitude depends, as is well known, on finding the accurate difference between the local time at a first meridian and the time at the meridian where the seaman may be, as the distance can be easily reckoned from the difference in time. At the period referred to, it was not difficult by means of the sun's altitude to ascertain with tolerable exactness the time of the meridan of observation, but it was very difficult for the seaman to find out what, at the same absolute instant of observation, was the exact time at his first meridian. To enable him to know this, two plans were suggested One was to procure more accurate timekeepers. The other was to find the time at the first meridian by a careful observation of the angular distance between the moon and some star or planet. As timekeepers suffi-

ciently accurate were not to be had, it was suggested the only choice was to work out in advance, and tabulate the exact angular distances, at a first meridian, between the moon and some well known stars. These distances were to be reduced to what they would be if seen at the earth's center, and to be arranged for any hour of observation. Now as the angular distance between a star and the moon is necessarily the same at the same moment of absolute time, if that distance be observed at the same instant from two stations not in the same longitude, the only difference in the observations will be that of so many hours of local time, according to the distance apart the two stations may be. And when from such difference in time, the difference in space is worked out in the ratio of 15 deg. to an hour the correct longitude is obtained. Charles the Second was informed in 1674 that such tables of lunar distances, if prepared in advance, would be of great value to English seamen. He referred the question to a commission, John Flamstead was known to one of the commissioners, and was consulted on the subject. The King learned, from Flamstead, no accurate data for such tables existed, and that the positions of available stars for such a purpose were nowhere catalogued with sufficient exactness to be of any service. The result was Greenwich observatory was founded and Flamstead was appointed Astronomical Observator, finding his own instruments, and receiving the munificent salary of £100 a year. He determined with great accuracy the positions of about three thousand stars, and made a large number of lunar observations. In 1724, five years before Flamstead's death, an act of Parliament was passed offering five thousand pounds reward for a set of tables which would give lunar distances to within 15 sec. of arc; such tables to be tested by comparing them with actual observation for a period of eighteen years and a half. Mayer, of Gottingen, worked out a set of tables and sent them in 1775 to be tested for the award, but died soon after at the age of 39. The *Nautical Almanac* was started in 1767, Mayer's tables being used in it. His wife received £3,000 of the award offered, and a like sum was given to Euler, whose essay containing the solution of the celebrated problem of The Three Bodies had, in 1748, received the prize of the French Academy. Euler's famous problem was: given their distances, velocities, masses and direction, what will be the path of one of three bodies around another, when all move in accordance with the law of gravitation?

The lunar method of finding longitude has fallen into disuse since the days of chronometers. For these we are indebted to John Harrison, a Yorkshire carpenter, who, I fear, would have utterly failed at a grammar school examination, but whose ingenuity in constructing a timepiece not affected by climate was nevertheless of inestimable service to his country. As his chronometers had the accuracy called for by the act of Parliament we before referred to, he received from the English Government in 1767 £20,000.

In the British *Nautical Almanac* lunar distances of several of the best available stars and planets east and west of the moon, may be found to a second of arc, by simple inspection, for every third hour of Greenwich time, with a simple method of estimating the difference for any intervening time. There is also given, for the same purpose, a list of moon culminating stars. The lunar distances are complete from Hansen's Lunar Tables of 1857; and are published in the almanac more than three years in advance. The precision with which the position of a ship at sea can now be determined was shown by the picking up from the bottom of the ocean, of the broken Atlantic cable, no larger in section than a ten cent piece; as all the buoys had been washed away, and nothing was left to the navigator to guide him in what looked so hopeless a task but his nautical skill to find the exact spot where the break had occurred.

Simultaneously with the advancement of lunar investigations in this direction much progress was made in the work of scrutinizing and mapping out the moon's surface. Without instrumental aid, only a faint indication of the more prominent objects on the moon's disk can be seen, and one is not surprised that some of the early selenographers thought these were but the reflected seas and continents of the earth. Galileo's 'perspective glass,' made by him about 1609, was the first known medium through which anything more than this was seen. He published his observations the next year. The quaint title of his book tells its own story, and is worth giving in full: "'The Sidereal Messenger,' announcing great and wonderful spectacles, and offering them to the consideration of everyone, but especially of philosophers and astronomers, which ~~been~~ have observed by Galileo Galilei, etc., etc., by the assistance of a perspective glass, lately invented by him, namely, in the face of the moon, in innumerable fixed stars, in the milky way, in nebulous stars, but especially in four planets which revolve around Jupiter at different intervals and periods with a wonderful celerity, which hitherto not known to anyone, the author has recently been the first one to detect and has decreed to call the "Medicean Stars." He constructed the first lunar map, and in a rough way calculated the height of some of the lunar mountains, to which his method gave too great a height. It is thought his first telescope could not have magnified more than seven diameters, and it is said to be beyond doubt he never used an instrument which magnified more than thirty diameters.

The "Selenographia" of John Hevel, or Hevelius, appeared in 1647. It marked an era in lunar discovery. Hevel was an extraordinary man. He made his own instruments, engraved his own maps and printed his observations with his own hands. His telescope magnified from thirty to forty diameters, and from the observations he made with it he constructed a map, showing two hundred and fifty lunar formations. For more than one hundred years Hevel's map remained the best map of the moon. The chief lunar formations he named after the earthly formations to which he fancied they bore the closest resemblance. Six of his names—the lunar ranges of the Alps and Appennines, and four promontories—are still retained. He discovered the moon's libration in longitude.

Telescopic observation, though with low powers, soon made it plain, from the same features being always apparent, that the moon had an axial rotation, and takes the same time to turn once round she takes to complete her circuit round the earth, and that these two movements keep almost the same half of her sphere always turned towards the earth. I say almost, because, as Hevel discovered, even the moon does not always show exactly the same face. She appears to gradually swing forward and as gradually to withdraw, first in one direction and then in the other, portions of the side of her sphere turned from us. The maximum measurement of this part of her sphere thus brought to view is about 7 deg. 53 min. of lunar longitude, equal to about a forty-fifth of her circumference. There is a similar change, though to a somewhat less extent, in latitude. This apparent shifting to and fro of the center of the moon's disk is called her libration in latitude and longitude. Libration in longitude arises from the time of the moon's axial rotation being always the same, while her movement of translation in her elliptic orbit varies with the change of distance from the earth. Thus, as the moon moves faster or slower in her orbit of translation, her equable axial rotation brings to our view east and west of her disk, portions of her sphere not seen when she is at her mean distance from the earth.

Libration in latitude is caused by the inclination of the planes of the lunar equator and orbit to the plane of the orbit of the earth; similarly the inclination of the axis of the earth causes the

terrestial poles to be turned towards and from the moon.

Another slight difference called the parallactic libration arises from the lack of coincidence between the station of the observer and the center of the moon's motion.

In 1651 Riccioli, of Bologna, published a lunar map, chiefly noticeable from its nomenclature. In lieu of Hevel's names, he designated the formations laid down on his map after a list of astronomers and mathematicians. A French astronomer says he shrewdly avoided the jealousy of his contemporaries by taking only the names of philosophers who were dead. His successors in this field of labor have marked his choice of names with approval, as more than two hundred of those he selected are still found on lunar maps. For the great plains Hevel had called seas and lakes, he retained Hevel's names, and suplemented them with others in addition indicative of the supposed influence of these parts of the moon on the earth. This notion has long been discarded, but the names remain, and astronomers still write about the lake of death, sea of tranquility and other names which were the outcome of an astrological fancy.

Thirty years later Cassinni published a lunar chart twenty inches in diameter, which was republished in France by Lalande in 1787. He was a skillful discoverer, and made important additions to lunar knowledge.

About he middle of the eighteenth century, Mayer, to whose lunar tables I have already referred, made preparations for producing a more complete lunar chart than had then been published; but died before his plans were carried out. A small map, however, eight inches in diameter, was published in 1775 with some of his posthumous papers, and this remained till 1824 the most accurate map of the moon to be had.

During the last quarter of the eighteenth century, the elder Herschel in England, and Schroter in Hanover, directed their attention to lunar investigations. They both worked with better instruments than those used by any of their predecessors, and used magnifying powers from one hundred and fifty to three hundred diameters. Herschel, whose splendid mechanical genius improved every astronomical instrument he touched, used micrometrical measurements in delineating the moon's surfrce, instead of trusting entirely to the skill of hand and eye, which, however, carefully trained, require for such work as this some mechanical assistance. Shroter's Selenotopographische Fragmente gave views of parts of the lunar surface with more details than had appeared in any preceeding book. He named many formations in the southwest part of the disk, and sixty of his names are yet retained. He first adopted the method still in vogue of designating the small spots in the vicinity of such as are named by letters of the Greek and Roman alphabets.

In 1824, Lohrmann, of Dresden, propose l to issue in twenty-five sections, a lunar map 36¼ inches to the moon's diameter, but, his sight failing him, only four of the sections were issued. As Lohrmann was a professional surveyor, was assisted by the astronomer Encke, and provided with a telescope made by Frauenhofer, of Munich, whose instruments of this class have never been surpassed, and but rarely equaled; it will be readily understood his work had rare merit and is still referred to.

In 1834-6 appeared the map of the moon, by Beer and Maedler, on a scale of about three feet to the moon's diameter, and the next year they published their great work "Allgemeine Vergleicheude Selenographie" to accompany and explain their map. Their labors carried lunar investigation far beyond the most advanced stages it had attained through the efforts of their predecessors. Their book for its comprehensive plan, and their map from the completeness of its topographical details, alike commanded a wide-spread and lasting appreciation. Though higher artificial powers than they used have since their time been applied to the working out of details on parts of the moon's disk, and some of their opinions have been rejected, their work remains a standard of reference. Their mode of working best shows the value of what they did. To fix their ninety-two chief points for further measurements, they made nearly a thousand micrometric measurements from these to the limb of the moon. They also measured one hundred and forty-eight of the more important formations with the micrometer. They made one thousand and ninety-five measurements of the shadows thrown by eight hundred and thirty different lunar mountains, noting all particulars of illumination. From the lengths of these shadows the heights of the mountains was then carefully computed, and the results served as standards for approximately determining the height of minor peaks when their shadows were projected under similar circumstances of illumination. They named one hundred and fifty formations not before named; but made no innovations on the accepted system of lunar nomenclature, except that in carrying out Schroter's plan of designating unnamed points by Greek and Roman letters, they used the Greek letters for elevations only, the Roman lower case letters for depressions and Roman capitals for measured points. Their telescope was a Frauenhofer refractor of 3¾ inches aperture, with a magnifying power of from one hundred and forty to three hundred diameters. As Lohrman had done before them, they followed Schroter's system of describing by numbers the relative brightness of the objects they observed. Their scale, which remains a standard, runs from zero for the deepest shadows to 10° for the brightest lights.

The ring plain *Aristarchus*, is given by them as the brightest on the moon. The *Oceanus Procellarum* is the largest gray plain; it contains an area of nearly two million square miles, covering a considerable portion of the northeastern and southeastern quadrants toward the south pole, and require favorable circumstances of libration to bring them into view in profile. Maedler measured one peak in the Leibnitz range at least 27,000 feet high, and others in the same range are thought by Schroter to have a height of nearly 30,000 feet.

Schmidt of Athens made a series of 1,000 drawings for a map 75 inches in diameter, which he finished in 1868.

The British Association in 1864 appointed a Moon Committee, of which, Mr. Burt, an able man, was appointed Secretary. They proposed to map and catalogue all the formations of the lunar surface. Their lunar map will be 100 inches to the moon's diameter, and the preliminary outline maps for its preparation, are on a scale of twice that size to admit of all details without crowding. The committee recommended the use of a telescope power of 1,000 diameters for preparing the outline maps, and as an increase in magnifying power is equal to a decrease of distance, a view through such a telescope would be equivalent to looking at the moon at a distance of about two hundred and forty miles. Several sections of this map are issued, but I am not aware if it be yet complete.

Four years ago Mr. E. Neison, F. R. A. S., gave to English readers a more complete treatise on the moon than was before within their reach, His work though based on that of Beer and Maedler, has much original merit. It contains his own constant selenographical observations during a period of eight years; a long series of observations placed at his disposal by the Rev. Mr. Webb and other observers who desired to aid him; and it also includes much of interest from Schroter and Lohrmann. His instruments were of the best class; a fine 6 inch reflector, and a With-Browning silvered glass reflector of 9⅓ in. speculum. The lunar map accompanying his book is in twenty-two sections and is on a scale of 24 inches to the moon's diameter. Although smaller than the map of Beer and Maedler, his chart contains several thousand more objects than theirs does, and it shows more rills than

are given by Schmidt in his *Rillen au dem Mond.*

Neison groups the entire diversely constituted, lunar surface, into: Plains, Craters and Mountains.

His plains include all the large dark tracts called by the early observers *Mares*; the smaller dark tracts, for which they used the name Palus, Lacus or Sinus, and the brighter even tracts, to which no special name had before been applied.

The craters for convenience of reference he divides into walled-plains, mountain-rings, ring-plains, crater-plains, craters, craterlets, crater-pits, crater-cones and depressions.

He also somewhat arbitrarily divides the mountains into great ranges, highlands, mountains, peaks, hill-lands, plateaus, hills, mountain ridges, hillocks, mounds, ridges, landswells.

To these groups are added the rills or clefts, a class of formations first seen by Schroter. Some of these run two and three hundred miles, and have baffled observers in making out their true character. Some contend they are fissures in the moon's crust, others think they look like river beds. Schmidt, in 1868, showed he had seen 425 of these peculiar lines, and the map of the British association will likely show one thousand.

Neison retains the same names Beer and Maedler affixed to the four hundred and twenty-seven named formations on their map. To these he adds eighty-six others, making in all five hundred and thirteen formations designated by names on his map. Each one is described in the order of its location, and for convenience of reference an alphabetical index of formations is also given at the end of the book. For every place named on the map there is given in the text the authority for the name; degree of brightness of the place; if a plain or crater, its dimension, and if a mountain, its height. The position in lunar latitude and longitude of almost every place is given, in most cases to minutes, in many to seconds. All the smaller unnamed spots of interests are described with the large named formations to which they are nearest, and observations respecting parts of special interest are given in detail, with name of the observer and the date of observation. Tables and a number of formulæ are added so as to make the work thoroughly serviceable to the student of lunar phenomena. As an illustration of its merits, I may add, the book was translated into German as soon as published.

Exquisite drawings of special craters have been made by Mr. Nasmyth, of Patricroft, and fine photographs have been taken by Prof. Rutherford and Dr. Henry Draper, of New York.

It is to this somewhat long list of charts and drawings we are primarily indebted for our present knowledge of lunar topography.

After all this mapping and minute measuring one might think our knowledge of the lunar surface must be nearly perfect, and that minute changes would be easy of detention. Such, however, is hardly the case. It is true no important formation could disappear, or materially change in appearance, without notice; but it is by no means likely any changes similar to ro even considerably in excess of such pyhsical changes as the earth is undergoing would be detected.

The wonderful change in appearance an object may present under different conditions of illumination was not so well understood when high telescopic powers were first applied to lunar observation as it is now. The result was, some of the best observers fell into grave errors respecting supposed changes on the surface of the moon. One hundred years ago the elder Herschel with all his acumen and strong common sense, thought the moon was inhabited. And more recently still, Gruithuisen, of Munich, suffered a wild imagination to distort and play pranks with the real pictures his keen eye had actually seen through his splendid instrument. He imagined he saw trees, buildings and cities in the moon, and proposed to issue a book on The Habitability of the Moon, and Traces of its being Inhabited. All such visionary conceits as these however, have hardly existed since the labors of Beer and Maedler. The only case of lunar change which has been at all sustained by admissible evidence was that of the crater Linne, brought to public notice about twelve years ago by Schmidt, of Athens. What gave weight to the Professor's words was the knowledge that he had made during twenty-five years thousands of lunar drawings and measurements, and his repeated contention that during the whole period of his lunar studies, he was confident no change on any important scale bad taken place on the surface of the moon From such an observer the following letter to Mr. Burt could not fail to arrest attention: "For some time past I find that a lunar crater, which Maedler named Linne, situated in the plain of the Mare Serenitatis has been invisible. I have known this crater since 1841, and even at the full it has not been difficult to see. In October and November, 1866, at its epoch of maximum visibility, this deep crater, 5-6 miles in diameter, had completely disappeared, and in its place had appeared a little whitish luminous cloud. Be so good as to make observations in this locality." For the next two years Linne was closely watched. At first nothing but a nebulous spot could be seen Then Schmidt saw a small elevation in its center and Father Secchi at Rome detected a minute craterlet. Since 1868 its appearance has been unchanged.

There is room here for but one of two conclusions. Either all accounts of this crater prior to 1866 were wrong, or the crater itself has undergone a remarkable change. Either conclusion has its supporters, though the majority incline to a belief that the early observers of Linne were wrong. That there should be any difference of opinion respecting the disappearance of a crater so large as Linne is remarkable. Still it must be borne in mind the minimum visible under ordinary circumstances on the moon's disk, is said to be an object three hundred feet high and a mile long, though a detached steep object not more than fifty feet high might possibly be detected by its shadow if that shadow were projected on a level surface. A degree of lunar longitude or latitude at the center of the moon's disk, when she is at mean distance, which equals nearly nineteen miles, subtends an angle of about sixteen seconds and a half, or an angle of a second of arc will cover a space more than a mile and a tenth long. The almost infinitesimal space a second of arc is may be better appreciated by bearing in mind that it takes a fine telescope, magnifying four hundred times, with a fine night and keen eye, to separate two bright objects, like a double star, that are half a second apart.

As on most other subjects where there is independent thought, there is, no doubt, a difference of opinion amongst astronomers as to the physical change the moon has undergone and is still undergoing. Nasmyth, the inventor of the steam hammer, who has been for years a close lunar observer, thinks if we except the contraction and expansion of the lunar crust from variations of temperature the moon now undergoes but little change; and that she is devoid of water, atmosphere and soil. On the other hand Neison contends, as it is probable the earth and moon were primarily identical in substance, it is equally probable their changes have been analogous, and are chiefly modified by the difference in size of the two bodies.

That there must be a great variation of temperature on the lunar surface, through its exposure for fourteen successive days to the sun, and through its radiation of heat into space for a like time, admits of no doubt. But what the maximum and minimum of lunar temperture may be, there are but few data on which to base an opinion. The great reflector of Earl Rosse with its six foot speculum, has been brought into use in investigating the lunar temperature. Earl Rosse himself regards his investigations as but

tentative and approximate. He estimates the heat radiated to the earth from the full moon is equal to the heat which would radiate from a globe of the moon's size and position if it were kept at a constant temperature of one hundred and ten degrees centigrade. This it has been estimated, would give a maximum temperature not exceeding 200° and a minimum temperature not much below zero centigrade. To some extent this agrees with Sir John Herschel's opinion of the moon's climate: "An unmitigated and burning sunshine, fiercer than an equatorial noon continued for a whole fortnight, and the keenest severity of frost, exceeding that of our polar winters for an equal time"

Such a climate precludes the supposition that water can now exist on the moon, whatever may have been the case in times past.

The opinion of Bessel that the moon's atmosphere is about the one thousandth the density of that of the earth has till recently been the commonly received opinion. His conclusions were derived from an investigation of the refraction a ray of light undergoes in passing through the lunar atmosphere. Later research in the same direction has led to the opinion that the lunar atmosphere has a density greater than Bessel concluded it to have. A density one three hundredth part the density of the earth's atmosphere is given by Neison as agreeing with Prof. Airy's careful investigations of the refraction the lunar atmosphere produces.

Neison argues at some length that, as what must have been portions of the atmosphere and ancient seas of the earth are now locked up in the immense masses of our terrestrial strata, a similar process may have gone on in the moon; and that as she has a larger proportion of surface to her! mass the absorption of the lunar seas and atmosphere will have been proportionately more rapid. This, in his opinion, is the best possible explanation of the present non-existence of the seas which the moon appears at some early period to have had. This is a part of Neison's general theory: That the forces which have made both the earth and moon what they are, are analogous in nature if not in degree. To any one who has seen through a telescope the death like stillness which appears to reign over these quiet plains and sparkling mountains, this theory might at first sight seem false, but we must remember our own busy world at the same distance would seem as still.

There are few sights more impressive than a telescopic view of the moon under favorable circumstances of illumination. Who that has once watched the slow advance of a mountain-ringed lunar plain into the sunlight can ever forget the sight? Peak after peak stealthily peers through the gloom, each like some faintly sparkling gem in the darkness, the whole formation growing more distinct, and seeming nearer, till at length it stands suffused in light made brighter by the contrast of the cool gray lunar shadows.

Still, the best student of lunar phenomena has higher aims than to merely measure and name every tiny gray patch and ringed dot he can spy out on the moon's disk, or to please himself with pretty pictures of the lunar shadows hiding themselves away at the approach of the beaming sun. He is invulnerable to such shafts of satire as old Sam Butler hurled against the idle dreamers of his day, who cudgeled their wits merely to know

> "Whether the moon be sea or land,
> Or charcoal, or a quenched firebrand,
> Or if the dark holes that appear,
> Be only pores not cities there."

All these maps and measurements and all this scrutiny are but scaffolding to the building; means to worthier ends. How well these ends have been achieved, the merest glance at the history of lunar investigation cannot fail to show. And as this branch of knowledge has more than met the exactions of an age which does not fail to require *quid pro quo* for all outlay; and has the higher merit of having furnished us with our best clew to a rational conception of the marvelous order of the universe; are we not warranted in concluding so bright a past presages a still brighter future?

> "For we doubt not through the ages one increasing purpose runs,
> And the thoughts of men are widened by the process of the suns."

reign over
ntains, this
se, but we
at the same

sive than a
vorable cir-
at has once
mountain-
t can ever
stealthily
ome faintly
hole forma-
ning nearer,
light made
gray lunar

phenomena
neasure and
nged dot he
r to please
lunar shad-
approach of
able to such
rled against
dgeled their

nd,
brand,
ar,

and all this
he building;
ll these ends
ance at the
fail to show.
s more than
does not fail
lay; and has
hed us with
n of the mar-
not warrant-
sages a still

ages one in

lened by the